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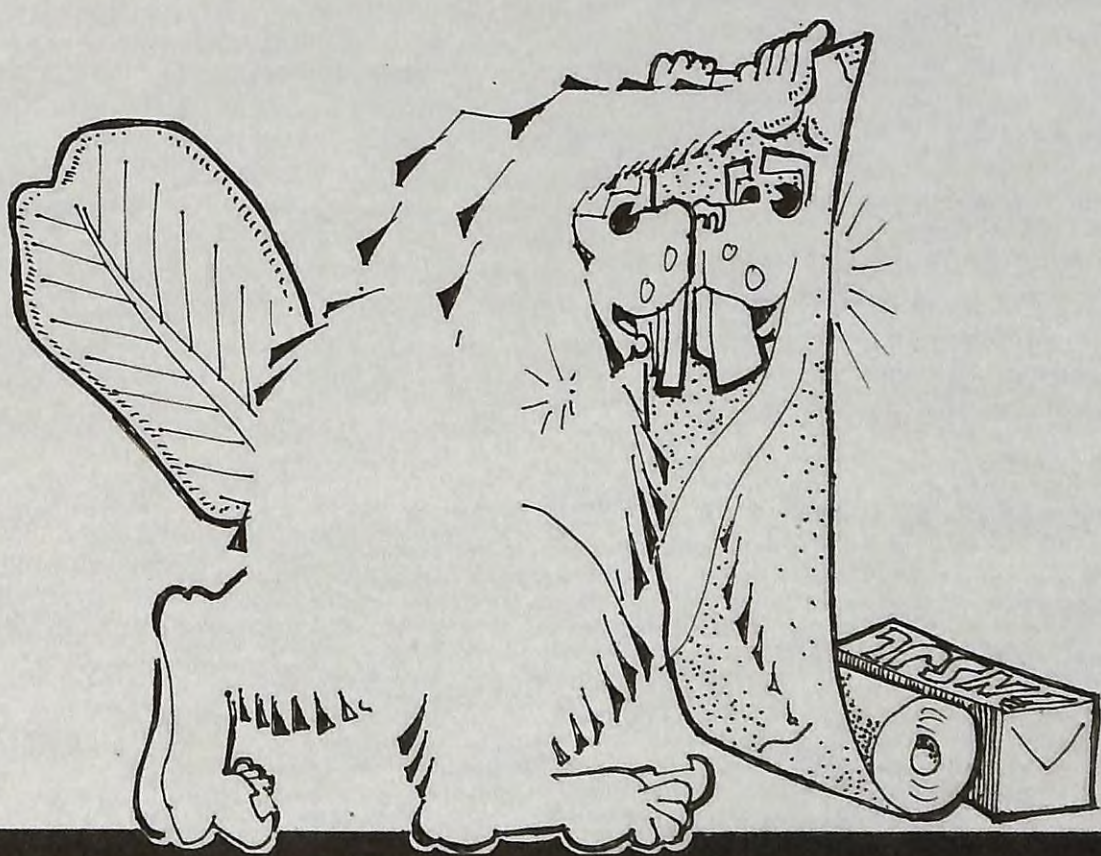
Reflective Insulation Systems



From the Editor . . .

So you think that energy prices are too high? The greedy oil barons are just getting fatter at your expense? There may be some truth to such ideas, but fundamentally it is a bigger issue that is also behind the critical climate change issue we are facing today.

Oil has been a part of our industrial society for only about 150 years. In that short time, we have used up a major portion of the oil that took millennia to be created and also impacted the global ecosystem. The debate about "Peak Oil" (the point at which worldwide production peaks, and starts to decline) has been raging for a number of years. Optimists – mostly oil industry types – still argue that peak oil is years away.

While there is much speculation that the recent jump in prices is influenced by geopolitical fears, the Iraq war, Nigerian political unrest, or simple oil industry profiteering, there are more fundamental issues involved. In real economic terms, oil prices have been low for a long time – $100 a barrel oil is the equivalent of 15 cents a cup. While we have no problems spending money – $2 for a small bottle of water, $5 for a cup of coffee, $15 for a movie or $100 for a sports event – we whine when we need to pay $1 for a litre of gasoline for our vehicle. Other than municipal water, nothing of any genuine value in the world is sold as cheaply as refineries purchase crude oil.

It was interesting to come across a paper prepared by a major American investment banker serving the energy industry. He, an industry insider, was decrying how the oil industry is living in a state of denial about oil production. Apparently, the oil industry reserve statistics everyone relies on, despite their veneer of scientific accuracy, are not much more than a collection of self-reported figures from industry. What is accurate are the production figures.

In May 2005, crude oil production reached a worldwide all-time high at 74.3 million barrels a day. This was the first time the world ever produced this much oil. No other monthly report before or since shows oil production at or above the 74 million barrel per day mark. In other words, there is evidence that peak oil has already passed and most have not noticed yet. An analysis of worldwide resources, including our tar sands, shows declining total production. However, world petroleum demand continues to grow, and we're all guilty.

The passage of peak oil in such a short time of human exploitation of oil resources that took millennia to create is a sad commentary on humanity's inability to manage the resources we were given on earth.

So what has all this to do with building, you ask? The building sector accounts for about one-third of total energy consumption for the construction and operation of homes and businesses. We know that we can do significant improvements. We can build homes and buildings that are very nearly energy independent, even in the cold regions of Canada. We just need to take action. Sadly, too many in our industry merely pay lip service to the need for more energy efficiency.

When proposals for upgrades to energy efficiency or environmental standards are made, we see a lot of resistance.

When we plan for and undertake work for new building and renovations, we need to become more aggressive with steps to reduce the environmental impact of the building sector. This means not only low embodied energy content for materials with recycled content, but also the energy efficiency of the whole building.

Richard Kadulski,
Editor

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Editor-Publisher: Richard Kadulski
Illustrations: Terry Lyster
Contributors: Kendra Slack, Rob Dumont, Paul Pettipas, Eric Gerrits, C.J. Schumacher, Troy Glasner, Janet Ansell
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Reflective Insulation Systems

Reflective insulation products have interesting properties. In some applications, they are extremely effective insulation materials. Think of spacecraft and astronauts – they would not be able to survive without taking advantage of reflective insulation materials. However, the extreme conditions experienced in space do not match the conditions found in the average building.

Similarly, animal barns, industrial buildings and ice rinks are usually poorly insulated. In a poorly insulated building, especially industrial or agricultural, any improvement will provide significant performance improvements, and in these environments reflective products provide some benefits.

However, these gains cannot be applied across the board to all building types and all applications. Yet we see persistent exploitation of extreme examples as a rationalization and marketing tool for reflective insulation products. It's almost as if the marketers catch sight of their reflection in the mirrored surface and enter into a trance where they lose all sense of reality.

When looking at performance improvement claims it is important to use some discretion to ensure their suitability for specific applications. Unfortunately, too many builders and designers are seduced by slick marketing to use products in an inappropriate manner. Foil-faced products can be used in the right location, for the right application. Regrettably, they are being pushed for inappropriate applications that do not even comply with the building code.

The P-2000 Insulation is one product that is misleading many builders. P-2000 is a type 1 expanded polystyrene insulation foam board that is foil-faced for use in residential and commercial buildings.

The manufacturer's installation details on their web site show how to install their foil-faced material on the exterior of the house and to tape the joints. This will help reduce thermal bridging and to achieve a more airtight building envelope. However, as any building professional knows, low permeability materials must always be placed on the warm side of the assembly. The problem is that the foil-faced P-2000 material has a permeability of 31 ng/Pa-sec-m^2, which qualifies it as a vapour barrier, because the building code defines a vapour barrier as having a permeability less than 60 ng/Pa-sec-m^2.

The Nova Scotia Home Builders Association issued a product alert recently. They point out that the Nova Scotia Department of Labour & Environment and the Nova Scotia Department of Energy have been reviewing the activities of the companies promoting and distributing P-2000. They believe there is sufficient information to warrant a complaint against these companies and individuals under the Competition Act for making false and misleading representations – representation not based on adequate and proper tests, and untrue, misleading or unauthorized use of tests and testimonials. A complaint was lodged July 13, 2006.

Intertek Testing Services NA, Inc. wrote in a letter on May 24, 2006:

> *"We are aware that our name has been used in connection with misleading R-value claims being made by Royalty's Research & Development (RR&D) Enterprises and some distributors of P-2000 foam insulation. Intertek did conduct comparative testing on P-2000 and fiberglass insulation products and issued RR&D Enterprises a test report. As outlined in the test report, the testing was conducted per the client's criteria and not in accordance with established, consensus standards or methods. As such, this data should not be compared to test data derived from standards-based test methods nor used as a method of demonstrating code compliance. In violation of Intertek's terms and conditions, RR&D Enterprises released marketing material using Intertek's name and report date without approval."*

Natural Resources Canada, in a March 2007 release entitled: "The Effective Thermal Resistance of Foil-Faced Bubble Insulation and other Similar Products Recognized by Natural Resources Canada for the Purpose of Modeling Homes under its Energy Housing Initiative" stated:

> *"If modeling a reflective foil film with or without a laminated layer of foam or fibre based insulation board and there is a dead air space of 12-22 mm (½ - 1") NRCan will accept an RSI value of 0.26 (R-1.5) for the foil and dead air space. If a layer of insulation is laminated to the foil with its adjacent air space, then also add the insulation's RSI/R-value. As noted, if there is no air space, then*

just calculate the value of the insulation (single-layer foil membranes without an air space have an RSI/R-value of 0)."

The challenge facing builders and designers is that some sales people are telling them that P-2000 has R-values as high as R-27 for a 1-inch panel. In fact P-2000 has an R-value of 3.89 per inch thickness based on P-2000's own tests using their foil-faced board (RSI 0.684).

CHBA's Technical Research Committee has also pointed out that reflective vapour/air barrier products and reflective sheathing can, if properly installed, provide additional thermal resistance to wall and ceiling assemblies, but to do so the surfaces must face an airspace.

The Canadian Construction Materials Centre at the National Research Council has limited listings for assemblies using reflective materials to wall assemblies only, and has indicated that the thermal resistance of a ¾" airspace with two reflective surfaces would be R-3.46 (RSI-0.61) for wall applications.

The absence of an airspace on either side of any foil insulation prevents any additional reflective thermal resistance. In such applications a foil bubble pack product can be expected to provide a maximum of R-1.5 (RSI-0.26), assuming the bubbles remain intact and unperforated. A CMHC Research study that found that bubble pack insulation provided little value when used in an under-floor slab application. The R-value of a concrete slab floor with bubble-pack under the slab was only R-2.3 (RSI-0.4).

Yet we hear that builders are using foil-faced insulation products under the slab to claim an R-12 because that is what the product sales people tell them. Simply put, that is not correct. Foil insulation should not be used under a slab-on-grade. Builders should be aware of the risk they take in compromising the performance of their floor systems relying on such bogus claims. ☼

Reflective Insulation Under Floors

A reflective film, bubble pack or otherwise, does not provide insulating value under a concrete slab, whether it is a slab-on-grade, or a basement floor. However, there is one location where reflective films provide significant insulation values and that is under a floor joist system.

In the case of a floor joist system (see fig 1), provided the floor is properly sealed and airtight, convection currents are suppressed because the upper portion is warmer. The heat is reflected back, reducing heat loss, and still air itself is a good insulator. Theoretical calculations suggest that the R-value or the air space plus the reflective foil approaches R-50. However, it is important to stress that this applies only to a horizontal element. In a vertical application, convection currents would overwhelm the space and there is no significant insulating value.

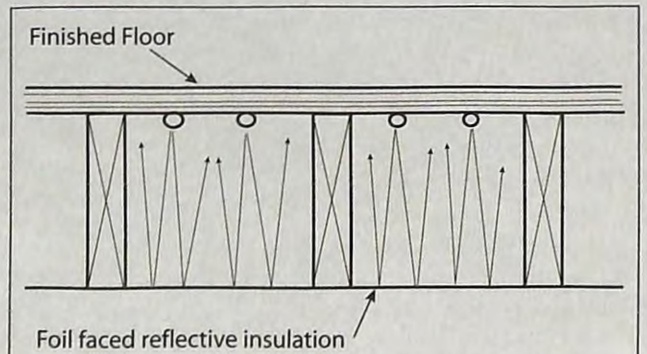

Fig. 1. Foil-faced insulation under floor joist system with in-floor heating. Floor assembly must be airtight.

Reflective Insulation In The Attic

Reflective surfaces in the attic are used in the southern US to reduce air conditioning loads. A reflective foil is tacked to the underside of the roof rafters or trusses to create a radiant barrier system. This is a simple way to reduce summer overheating. However, they do nothing to reduce space heating loads.

The Physics of Radiant Barriers

A "radiant barrier" is a reflective/low-emittance surface as defined by ASTM where the emittance is 0.10 or less on or near a building component that intercepts the flow of radiant energy to and from the building component.

The aluminum foil shields that are commonly inserted behind radiators in older houses are radiant barriers, blocking radiant heat transfer from the radiator to the exterior wall.

It should be clearly understood that although a radiant barrier reduces heat loss and gain through the building envelope because it is installed in vented cavities (like attics), it is not an insulation material per se and has no inherent R-value.

Radiant Barrier Systems

A "radiant barrier system" is a building section that includes a radiant barrier facing an air space. An attic with a radiant barrier on top of the mass insulation on the floor, or under the roof is a radiant barrier system.

From Understanding and Using Reflective Insulation, Radiant Barriers And Radiation Control Coatings by Reflective Insulation Manufacturers Association *www.rima.net*

Beware of "Radiant Barrier Paint"

There has been a lot of talk lately about radiant barrier paint. The problem is, according to definitions set forth by the American Society of Testing and Materials International (ASTM), there is no such product currently available. There are low-emittance paints, which are also known as interior radiation control coatings. These products have some benefits, however, many companies are marketing a "radiant barrier" paint, and there is a difference.

A radiant barrier is a low-emittance surface facing an air space. The thermal performance or the reduction of radiant heat transfer is proportional to the surface emittance of the radiant barrier material. Emittances of materials range between zero (no radiant heat transfer) to one (a black surface with maximum radiant heat transfer rate). Common building materials, such as wood, masonry, fiberglass insulation and gypsum board have high surface emittances of 0.8 or greater and therefore have high radiant heat transfer rates. Products defined as radiant barriers by ASTM have a reflective/low-emittance surface with an emittance of 0.10 or less.

ASTM calls paint an interior radiation control coating (IRCC) if the IR emittance is 0.25 or less (ASTM C-1321, *Standard Practice for Installation and Use of Interior Radiation Control Coating Systems in Building Systems*). The ASTM standard also identifies the method for measuring the emittance (C 1371, *Test Method for Determination of Emittance of Materials near Room Temperature Using Portable Emissometers*).

Interior radiation control coatings are not dependent on their thickness. They are considered as a low-emittance coating when applied to building materials such as plywood, OSB, metal siding or plasterboard according to the manufacturer's installation instruction, and will have an impact of lowering the surface emittance to less than 0.25. These products work by changing the emittance of the surface where it is applied.

When high emmittance materials such as gypsum board, plywood, brick are heated above the temperature of adjacent surfaces, they radiate heat energy to cooler surfaces. An IRCC lowers their surface emittance reducing the ability to radiate heat.

The Reflective Insulation Manufacturers Association (RIMA) conducted testing of several low-emittance paints in 2006 measuring the surface emittance of several paint products claiming reflective benefits that ultimately didn't even meet the qualifications for an IRCC, let alone a radiant barrier. Seventeen products were tested, but only four products met the qualifications for an IRCC. So, not only are IRCCs not radiant barriers but some paints are not even IRCCs.

Depending on the project, both radiant barriers and IRCCs might be able to contribute to the overall thermal performance of a building. However, it is important to be aware of what the properties are for low-emittance paints. If it's being called a 'radiant barrier paint' – Beware! Check the emittance, ask for test data and make sure it meets ASTM standards before you buy.

More information on radiant barriers and reflective insulation is available from the Reflective Insulation Manufacturers Association. ☼

This comes from a press release issued by Mary Edmondson, Executive Director of the Reflective Insulation Manufacturers Association (RIMA). www.rima.net

Geothermal Systems

Geothermal heating and cooling systems (also called earth energy systems, ground-source heat pumps or GeoExchange™ systems) are heat pumps that take advantage of the ground's heating and cooling properties (the same properties that make any basement cooler in the summer and warmer in the winter) to heat or cool entire buildings. For heating, they collect and transfer heat from the earth through fluid-filled, buried pipes running to a building, where the heat is then concentrated for inside use. These systems can efficiently provide space heating and cooling, cooling-only or heating-only functions. Although cooling-only and heating-only are possible, these are not commonly used and are not as economical. Doing both heating and cooling as well as domestic hot water improves the operation and efficiency of the system thus eliminating the need for separate furnace, air-conditioning and hot water heater systems.

Ground-source heat pumps do not create heat through combustion - they simply move heat from one place to another. This heat 'exchange' between the ground and the building is accomplished by using conventional pump and compressor technology to provide an alternative to traditional oil-, or gas -fired heating, and air conditioning (HVAC) systems. In locations where electricity is a major, or preferred fuel option, the high efficiency of these systems reduces electricity use significantly. Geothermal is best for locations with space (as in the countryside), where there is no gas, and as a replacement for oil, propane and electric resistance heating.

A ground-source heat pump consists of one or more factory-made components that normally include an indoor fan coil, compressor(s) and refrigerant-to-fluid heat exchanger(s). In addition, some or all of the domestic water heating can be provided through the use of a desuperheater, integrated demand water heater or a separately installed compressor that provides demand water heating. It uses the thermal energy of the ground or groundwater as the heat source and heat sink for residential space heating and cooling.

In cooling mode, typical central air conditioners may have a SEER of 13 or higher, while geothermal systems may have an energy efficiency rating of around 20. With window and central air conditioners, as the outdoor temperature increases, the energy efficiency rating decreases, thus increasing power consumption. On the other hand, geothermal systems operate at roughly the same efficiency rating regardless of the outdoor temperature, which is important in areas that may have electrical systems that are at brownout or near brownout conditions.

In the heating mode, geothermal systems add electric demand compared with fossil fuels. However, compared to electric resistance space heating (baseboards, electric furnaces) geothermal systems reduce electrical demand, and avoid emissions when the electricity is generated by hydro or other renewable sources. In general geothermal systems reduce the total amount of purchased energy because of the higher coefficient of performance (COP). To receive ENERGY STAR qualification, ground-source heat pumps must achieve a minimum COP of 3.3 for closed loop systems, 3.6 for open loop, and 3.5 for direct expansion (DX).

Ground-source heat pumps are especially efficient in locations where there are also substantial cooling loads, and where the primary heating option is electricity. The high COP means that the same amount of heat can be provided for less energy input. For new homes, the system design can be optimized to match lower heating loads and the ground loop infrastructure will have less impact on the site when installed during construction. In new developments, the higher initial cost of geothermal systems can be offset by using the systems as a community heating energy system, where a single system serves a number of dwellings. This is quite a common approach in Scandinavia. We now have a number of district heating systems installed in Canada, and this practice will increase with time.

The energy resource in the ground is tapped several ways

- Through a Closed Loop System in which the heat transfer fluid is contained in a closed system;
- Through an Open Loop System in which the heat transfer fluid is part of a larger environment. The most common open loop systems use ground water or surface water as the heat transfer medium;
- Direct Expansion (DX) in which the refrigerant is circulated in pipes buried in the ground, rather than using a heat transfer fluid (such as water or antifreeze) in a separate closed loop and fluid-to-refrigerant heat exchanger. A DX system includes all of the equipment both inside and outside the house.

Although geothermal systems offer proven economic benefits in Canada, their application has largely been in areas under-served by natural gas. Market penetration for geothermal systems is still less than 1%. A major barrier to growing the industry has been a lack of an infrastructure ensuring high professional standards and capacity. The lack of a properly trained and accredited pool of installation and service contractors including in the design community, has been identified as a bottleneck to the growth of the industry.

Today the industry is using the term "GeoExchange™" to describe these systems. The Canadian GeoExchange Coalition (CGC) was created in 2003 at the initiative of the Canadian Electricity Association and industry stakeholders with support from Natural Resources Canada to foster the development of the ground-source heat pump industry in Canada. One of the key actions by the CGC is the development of professionally accredited Canadian geothermal drillers, installers and designers. Industry professionals are being accredited and a comprehensive training and certification program is being introduced to address the limited availability of experienced drillers, installers and designers.

The CGC Global Quality GeoExchange Program® is a Canadian developed comprehensive voluntary quality assurance program. It includes training and accreditation for drillers, designers and installers; qualification of design firms and installation contractors; certification of GeoExchange projects; and arbitration between parties.

The CGC training courses were developed by industry specialists and researchers during the past three years. The training includes four modules — a drillers' course, an installers' course, a residential designers' course and a commercial designers' course. Courses have been offered across the country by qualified trainers in cooperation with CGC partners since February 2007. Successful completion of one of the courses is required in order to obtain industry driven professional accreditation in Canada.

The ***Manitoba Geothermal Energy Alliance*** (MGEA) is a separate non-profit, Manitoba-based industry association with a focus to provide information, education, training, certification and resources for the growing geoexchange industry in Manitoba. MGEA and the CGC signed a formal partnership agreement on December 11, 2007 to fully coordinate national and local programs in the province of Manitoba.

For information: *www.mgea.ca*

GeoExchange BC is a separate non-profit, BC-based industry association. It is our understanding that discussions are underway to facilitate the delivery of the CGC training and other programs in BC. They are also working with the Thermal Environmental Comfort Association (TECA) in their initiative for the Certified Heating Technician (CHT) Program that is now registering apprentices.

For information: *www.geoexchangebc.ca*

For more information including a current list of accredited installers, designers, and drillers, contact the Canadian GeoExchange Coalition at *www.geo-exchange.ca* or 1-514-807-7559.

Coefficient of Performance (COP) – A measure of efficiency in the heating mode that represents the ratio of total heating capacity to electrical energy input.

Energy Efficiency Ratio (EER) – A measure of efficiency in the cooling mode that represents the ratio of total cooling capacity to electrical energy input. For DX systems, the EER is calculated in accordance with CSA Standard C748-94 Performance of Direct Expansion (DX) Ground Source Heat Pump conditions.

There are federal minimum energy performance requirements for both ground-source (closed loop) and water-source (open loop) heat pumps. Performance ratings are determined by test method CSA C13256-1, must be verified by a 3rd party, and reported to NRCan. Efficiency requirements can be found at <u>http://oee.nrcan.gc.ca/regulations/jan2005_ground-water-heat-pumps.cfm?text=N&printview=N</u>

R-2000

For information on the R-2000 Program, contact your local program office, or *http://oee.nrcan.gc.ca/* (follow links to residential) www.R-2000.ca

ecoENERGY Retrofit – Grants for Geothermal Systems

The ecoENERGY Retrofit – Homes grant program (which is matched in some jurisdictions by local grants) offers incentives for ground-source heat pumps. In order to qualify for grants, the system must meet the CAN/CSA-C448 Design and Installation of Earth Energy Systems standard.

Until April 1st, 2008, the system installer must complete a "CSA 448 Design and Installation Compliance & Commissioning Report" (available from the Canadian GeoExchange Coalition), forward it to the Canadian GeoExchange Coalition and provide a copy to the homeowner. The homeowner must then show this copy to the energy advisor at the time of the post-retrofit evaluation in order to be eligible for a grant.

As of April 1, 2008, all eligible systems must be certified by the Canadian GeoExchange Coalition and therefore must be drilled, designed and installed by professional(s) accredited by this coalition, and the "GeoExchange™ System Certification Form" available from the Coalition will have to be used.

Masonry Fireplaces

Masonry fireplaces on an outside wall are, simply put, trouble. It's not the trouble associated with the maintenance of the fireplace – their operation can actually be unsafe. In winter, if the fireplace is located below the neutral pressure plane of the building and installed on the outside of the building envelope, it will go into flow reversal during standby conditions when the temperature of the air in the chimney falls below that of the heated space – and this can happen even as the fire is smoldering as it dies down so the toxic fumes are draw into the house. The result is inherent instability of the venting system that can introduce contaminated air and products of combustion to the living space. There is also the matter of heat loss through the uninsulated masonry on an exterior wall. Yet it is surprising that we still see such designs. They are seen on some very expensive custom homes.

The way to deal with wood burning appliances is to keep the chimney flue inside the airtight, heated envelope of the house. The chimney should not penetrate a wall of a building. Rather it should be installed or built so that it is enclosed within the heated space up to the point at which it exits through the building envelope through the ceiling.

Fig 2. This home has a large uninsulated concrete structure on the exterior wall that includes a wood-burning fireplace.

Fig 3. This fireplace (in a new home) shows another major concern about masonry fireplaces on the exterior. Because of requirements to maintain a clearance between combustible materials and the fireplace, the gap between the framing and fireplace seldom gets properly detailed and air-sealed. As we try to improve the energy efficiency of houses, these holes must be addressed.

What Were They Thinking Of?

Most single family houses are built by builders with minimal outside professional involvement other than the review done by the local building inspector. Even in the case of those houses where there is outside professional involvement, it is surprising to see how often questionable details and practices are used.

It is also sad to note how muzzled building inspectors are when it comes to commenting on building practices and details that are outside a very narrow range of code compliance issues. It is either a case where the building official himself is uncomfortable with commenting, or has been expressly muzzled by the legal department in the name of liability avoidance.

It is sad how often I hear builders and homeowners say they want to ask for additional feedback from their building official but are rebuffed at every turn. Granted, the inspector's job is not to provide advice, but there is plenty of scope to add comments beyond a very narrow code compliance review.

In my travels, I have the opportunity to see many job sites. It is always instructive to note the many ways that best intentions get sidetracked. It is amazing to see good ideas butchered by sloppy installations. As the old adage goes, a picture is worth a thousand words. We thought it worthwhile to show a few examples of seemingly obvious screw-ups that get built.

By far the biggest problems are ventilation systems. Duct layouts should be designed to allow for the required airflows. None of these systems are in R-2000 houses, which receive more scrutiny and inspection of the ventilation system (although these types of situations do occur from time to time even in R-2000 homes).

Fig. 4. Looking at the tangle of ducts at this heat recovery ventilator one wonders if there will be any air delivered where it is wanted, nor any collected from the desired exhaust points. The airflows in a typical HRV system are small – for the average house, depending on the number of rooms, it may be only be 60-100 cfm continuous at low speed and double that at high speed. Each splice, joint and elbow in the ducts represents resistance and air leakage unless the duct is sealed, which was not done in this case. Also, two ducts to the HRV must be fully insulated and sealed, from the outside to the HRV, as they are on the cold side of the unit.

Fig. 5. A common problem with HRV installations, especially on the west coast, is that they are placed in the attic. Placing an HRV in the attic effectively places it outside the heated envelope with the associated problems of heat loss and condensate drain freeze up. Although in this installation the ducting in the attic is fully sealed and insulated, the servicing will be impossible. Not only is the access going to be a problem – since the attic access is not even close to this unit – as can be seen, the hinged door cannot be opened to service the filters and core because the roof truss is immediately in front of the door. And just to make sure that access is more difficult, the strap holding up the unit is wedged against the door.

Fig. 6. A reasonably well-installed HRV system except that they forgot to insulate the ducts on the cold side of the HRV. Then again, it looks like they forgot to review the plans when designing the system layout at the cost of extra sheet metal ducts and loss of airflow.

Fig. 7. If we can dream it up, why don't we do it? The typical HRV installation does not have an effective targeting of exhaust flows. When one bathroom calls for extra exhaust, the increased ventilation is shared with all other exhaust ports. This is one builder's attempt to provide zoning for their exhausts. It works, but it will require a mechanic to figure it out when servicing is going to be needed.
Only one manufacturer we are aware of has a designed, off-the-shelf system with zone controls to bias airflows from specific locations.

Fig 8. So who needs working drawings and phonebook-sized specifications? Then again, what happens when litigation is launched? How did city hall deal with approvals on this project, even if it only is tenant improvements?
I've never seen site details so thoroughly worked out on-site, which implies the tradition of the craftsman design builder and working out details on-site is still alive and well – at least in Japan. This was spotted on a job site for a small retail shop in central Tokyo, across the street from a major five-star hotel.

Technical Research Committee News

Radon Guidelines

Radon and radon remediation has become a top of mind issue recently because of Health Canada's change to the radon guideline action limit to 200 Bq/m³ within occupied areas. This new guideline matches the action limits in most industrialized nations.

Radon is a radioactive gas that is colourless, odourless and tasteless. It is formed by the natural breakdown of uranium in soils and rocks. It breaks down further to form additional radioactive particles called radon daughters. When radon enters an enclosed space, such as a home, it can accumulate to high levels.

The concern with radon is that, on average 10% of lung cancers are attributable to radon exposure – an estimated 1,900 lung-cancer deaths per year in Canada. The risk for smokers is much higher than for non-smokers.

Radon is heavier than air and so tends to accumulate in the lowest parts of a building, such as a basement or crawl space. Radon concentrations fluctuate seasonally, but are usually higher in winter than in summer, and are usually higher at night than during the day. This is because buildings are more airtight, and doors and windows are closed at night, so that there is less outdoor air drawn into the house, allowing radon to build up. A home with continuous ventilation, such as with a properly installed heat recovery ventilator, should have lower radon levels.

The air pressure inside a house is usually lower than in the soil surrounding the foundation, so that radon and other soil gases can enter into the house. Radon can enter a home through any cracks in foundation walls and floor slabs, construction joints, gaps around service pipes and support posts, floor drains and sumps, cavities inside walls, and water supply pipes that are in contact with the soil.

Radon concentrations differ greatly throughout Canada but are usually higher in areas where there is a high concentration of uranium in underlying rock and soil. There are proposals to develop maps showing areas with high radon potential. Local health departments may have preliminary information on this. However, radon concentration levels will vary from one house to another, even if they are similar and next door to each other. The only way to find out if a house has a radon problem is to measure the radon concentration inside it.

Remedial measures should be undertaken in a dwelling whenever the average annual radon concentration exceeds 200 Bq/m³ in the normal occupancy area. The normal occupancy area refers to any part of the dwelling where a person is likely to spend more than four hours per day. This would include any finished basement room or a basement apartment. It would exclude an unfinished basement, a crawl space, or any area that is normally closed off and accessed infrequently, e.g., a storage area, cold room or laundry room.

The challenge for new homebuilders is that radon concentrations cannot be identified until after the house is completed, and then the measurements can only be done over a period of time, and generally during winter months. Thus new house construction should employ techniques that will minimize radon entry and will facilitate post-construction radon removal, should this subsequently prove necessary.

Construction to minimize radon concentrations in the house will also reduce moisture and soil gas entry into the house.

Canadian Home Builders' Association

The Technical Research Committee (TRC) is the industry's forum for the exchange of information on research and development in the housing sector.
Canadian Home Builders' Association, Suite 500, 150 Laurier Ave. West, Ottawa, Ont. K1P 5J4
Tel: (613) 230-3060
Fax: (613) 232-8214
e-mail: chba@chba.ca
www.chba.ca

Health Canada guidelines suggest that the aim should be reduce the radon concentration to less than 200 Bq/m³. If the radon concentration is found to be more than 600 Bq/m³, the remedial actions should be completed in less than one year; if between 200 Bq/m3 and 600 Bq/m³, the remedial actions should be done in less than two years.

If a radon test is above the guideline action limit of 200 Bq/m³, the following steps can reduce occupant risk:

1. Increase the ventilation in the basement to allow an exchange of air.
2. Seal all cracks and openings in foundation walls and floors, and around pipes and drains.
3. Paint basement floors and foundation walls with two coats of paint and a sealant.
4. Ventilate the basement sub-flooring by installing a small pump to draw the radon from below the concrete slab to the outside before it can enter your home.
5. Renovate existing basement floors, particularly earth floors.

More information about radon is available from the Health Canada website, at: *http://www.hc-sc.gc.ca/* and follow the links to Environmental & Workplace Health, and then radiation.

There is no way to be able to anticipate potential radon concentrations in a new home. However, it is appropriate to prepare for future radon remediation in new construction:

1. Ensure there is a porous layer under the house (drain rock, no fines gravel, etc.).
2. Seal under-slab poly membrane.
3. Seal foundation floor to foundation walls.
4. Ensure service penetrations through foundation walls and floors are caulked and sealed.
5. Use floor drains with back-flow prevention dampers.
6. Install a PVC pipe into the porous layer under the house, and cap it in the basement, to allow for future installation of additional pipe and fan to actively depressurize the soil under the house, thus minimizing radon penetration into the house.

Some builders are choosing to install a PVC pipe to connect the area under the slab through to the attic, and capping it there, avoiding future costly expenses should a fan installation need to be made.

Letter to the Editor

Re: Editorial, Solplan Review 137 (November 2007)

I enjoyed your editorial. Do you think the municipalities are starting to get gun shy about anything new on the market? Have these rain screen products you are talking about been in use long term (+5 years) in other jurisdictions? We (municipal departments) must be starting to look like dinosaurs or the last bastion of sensibility in this feeding frenzy of "green" and new age ideas.

Your article jogged my memory about a book I read last year called the "Tipping Point" by Malcolm Gladwell. It lays out how trends start and why they end and the major players involved. I think it may be a reason why manufacturers have a problem bringing new ideas on-line. I wonder who could be considered the laggards in this scenario – inspectors or builders as a whole?

I really think we as an inspection body (and the Building Officials Association of BC appears to be thinking about this) have to be careful to not be so indecisive and not keep up with industry to the point that we are no longer relevant. I think there is a saying on getting better – "if you are not continually getting better, then you are falling further behind."

I would also like to compliment you on your write-up on spatial separations. It is one of the first code/design articles geared to a mass audience. I really have to believe that this is never taught in design school. I would guess that 90% of residential builders, 80% of home designers and 50% of architects do not have a good understanding on how *unprotected openings* and *exposing building faces* relate to limiting distances.

I feel like I'm speaking in tongues when I try to explain this to most people. I would say this lack of understanding of basic spatial separation principles is even more acute outside of metropolitan Vancouver. It probably doesn't help that different municipalities have different interpretations, comfort and skills levels on this issue. I think the biggest problems occur when residential designers move into multifamily and light commercial projects. Maybe it would be good to have more information in future articles about sprinkler alternatives or is that an alternative we should avoid?

Keep up the good work.

Ken Kunka AScT, RBO
Okanagan Valley

Thanks for your comments. It is not just a matter of how long a given material has been in use, or what certification it has. It also requires the use of discretion and applying building science and engineering principles when considering alternative details. Interpretations cannot and should not be done lightly, but at the same time, when reasoned arguments are made, documentation provided (more than somebody's anecdotes), and in the final analysis, professionals agree to take responsibility, then there should be some movement.

Although code development is subject to extensive discussion and review, it is important to recognize that at the end of the day, there are limitations in the code. Generally, codes are reactive, being slow to change and then only after a long process of research and investigation. Ongoing research and field experience may alter the basis on which the code is developed, and point the direction for improvement. Nothing is ever static. So dealing with a changing understanding does require the use of discretion and common sense. To insist on compliance with third party certifications as the only justification for acceptance of a new product, rather than reviewing the justification on its technical merits, is not doing anyone any favour, nor is it protecting the building owner nor the municipality from risk.

Common sense tells us that a biodegradable material (wood) is subject to decay. Insisting only on the use of wood to create a rain screen cavity, rather than permitting alternatives that may be more water resistant is one example of short-sighted thinking.

The issue is not so much one of being relevant or not – there is a place for the municipal inspection service. Everyone benefits from another pair of eyes. Rather, it is whether or not the application of that service is done with the application of common sense and building science principles, or just a slavish adherence to a document in the hope of minimizing risk only to the authority.

What is often forgotten is that building codes, which are minimum standards, are always reactive. Building science knowledge and understanding is always evolving, so codes tend to play catch-up. That is why building officials need to use some discretion with code application, and when dealing with proposed details that seem to be a bit different. Engaging in meaningful dialogue with other building professionals is part of that.

As to code articles, we'll have to consider some items for the future. Ed.

Unvented Vaulted Ceiling Performance Test Results

Attic spaces are ventilated to remove moisture that is introduced by warm, moist indoor air that leaks into the roof assembly and to control ice dams in cold climates by minimizing roof temperatures. The practice of ventilating roof assemblies has been convention since the 1940s although little research went into the criteria. Experience and research over the past 10 to 20 years have caused many to question and abandon ventilated roof assemblies in favor of unvented cathedralized attics.

In hot climates, unvented cathedral roof assemblies prevent the warm, humid air from condensing on cool, inside drywall surfaces or on the cold surfaces of air conditioning ductwork in the attic. In cold climates, ventilation of roof assemblies can result in higher moisture levels and unvented assemblies may mitigate this problem. In cool coastal areas, unvented assemblies are less likely to suffer from moisture problems related to wind-driven rain, which can enter through vents and wet-sensitive materials in the roof assembly. In extreme cold arctic climates, fine blowing snow can enter though attic vents, which is why it is now standard practice in the north not to ventilate attic spaces.

Good arguments can be made for the use of unvented cathedral attic assemblies. Unvented roof assemblies, created by eliminating ventilation and moving the thermal insulation and air barrier from the ceiling plane to the rafters immediately below the roof deck, are increasingly common in low-rise residential construction.

Recent changes to the US International Residential Code allow the construction of unvented roof assemblies. At this time, the National Building Code of Canada has not made the same change, although there is a provision that allows unvented roof details provided it can be shown that an airtight assembly is achieved. Local building officials have permitted the construction of unvented roof assemblies in some jurisdictions. The most common way this is achieved is by the use of spray-in-place foam insulation.

Moisture performance of roof assemblies has been the focus of few North American field measurement studies. To determine whether

or not an unvented ceiling assembly that meets the new IRC code requirements can perform satisfactorily in the wet climates of Vancouver, BC, a house using this detail was instrumented and monitored continuously for two years. The ceiling assembly was built without a membrane vapour barrier and using an air impermeable, low density, open cell sprayed polyurethane foam insulation. The house is heated with radiant floor heating and year-round ventilation is provided by an HRV.

The roof assembly was asphalt shingles on ½ in. plywood sheathing on 2 x 4 strapping on 2 x 10 inch rafters spaced 16 inches on centre filled with 10 ½ inches of Icynene, a low-density, open-cell sprayed polyurethane foam and ½ inch drywall painted with a low permeance drywall primer. A polyethylene vapour barrier was not used.

Data was collected over the course of the first two fully occupied winters. The second summer, inspection openings were made to take moisture content readings with hand-held meters and collect some painted drywall samples for permeance testing.

The first year, the north-facing roof had high initial moisture content (MC) readings (in the range of 20-25%) for a short while, the result of high indoor moisture levels associated with the finishing work, such as drywall mud, painting and cleaning, etc.

The second winter (the first fully occupied winter), the sheathing MC at the north-facing locations increased to the high teens and low twenties while the south-facing roof only increased to the low teens. The south-facing roof appears to dry quickly by mid-February while the north-facing roof appears to increase in MC until the end of February and then dry during mid-March through mid-May.

Some concern was raised over the elevated MC levels measured on the north-facing roof. Test cuts were made through the drywall and the foam insulation in the roof during the second fully occupied summer. None of the samples showed any signs of mould or decay – the interior surface of the roof sheathing plywood was clean and the material resisted penetration of a pocketknife just as new plywood sheathing would.

The test cuts confirmed that there was good continuity of the sprayed foam insulation and a tight bond between it and the roof sheathing indicating that air leakage had no effect on the hygrothermal performance of the roof assembly.

Drying would have been accelerated by ventilating the house with drier winter outdoor air. However, the homeowners did not operate the heat recovery ventilation (HRV) system and did not switch it to "winter" mode until December. The HRV ran at a higher ventilation rate for all of the second winter, so that indoor temperatures were slightly cooler and RH levels were noticeably lower during the second winter.

In the third winter (the second fully occupied winter), indoor moisture levels were lower and the increase in moisture content was not as significant. The MC of the sheathing at the north-facing locations increased by 5-7% to the mid to high teens while the sheathing MC on the south-facing roof only increased by 1.5 – 3%.

The combination of the painted drywall and the air-impermeable, low-density, open-cell sprayed polyurethane foam eliminates air movement and the moisture in the exfiltrating air and reduces the outward diffusion of water vapour during cold weather. The vapour permeance of the interior layers of the assembly is sufficiently high to allow any moisture in the sheathing to dry inward during warm weather or in the event of incidental wetting.

The vapour permeance of the finished drywall samples was determined to be about 450 ng/Pa s m for samples finished with two coats latex paint, which was significantly higher than expected. Numerous vapour retarder primer paints are available that have a demonstrated permeance in the range of 35 to 57 ng/Pa s m, 10 to 30 times lower than measured and within the code defined criteria for vapour barrier. Use of these primers will significantly reduce the diffusion during the winter so that the moisture content of the north-facing roof sheathing does not exceed 20%.

Field Performance of an Unvented Cathedral Ceiling (UCC) in Vancouver
By C.J. Schumacher and E. Reeves, PEng.
Paper presented at Buildings X Conference, Florida

You Asked Us About: Environmentally Preferable Furnace And Water Heaters

We are planning a new home and would like it to be energy efficient and environmentally appropriate. What we would like to know is whether a high efficiency natural gas furnace and water heater is better and more cost effective than an electric one?

There is little difference between electric and gas as fuels – which is more environmentally preferable will depend on the location of the house and fuel options available in the region. All high efficiency equipment will provide equivalent performance – the difference may be more in cost based on differences in basic energy cost between the two fuels. Generally, on a per unit or energy basis, electricity tends to be more expensive than gas, but it will vary.

In some regions the electrical utilities are discouraging the use of electricity for space heating because of power supply issues. Electricity is best used for applications that have no alternatives, such as to light lights, run refrigerators, motors and computers. In other regions (such as BC at this time) the difference in energy cost between various fuels is very slight, but the use of electricity for space heating is still a concern to the utilities.

If electricity is considered for space heating, then you should consider a heat pump system (air-air can be used, especially in milder climates). A high efficiency heat pump can provide, on average, 2-2.5 kWh for every kWh it consumes (you might think of it as 200-250% 'efficient'). However, as the temperature dips below freezing, the efficiency disappears. Depending on manufacturer and model, the limit is around -5°C at which time a supplementary heater needs to be used. In milder climates, the number of hours that are below the threshold where supplementary heating kicks may be quite small, so that it will not be used much. That will not be the case in colder climates.

The most important and cost effective point to consider when looking at heating equipment is to make sure that the house is built as energy efficient as possible to reduce the building's energy needs for space heating in the first place. You want to make sure you use higher insulation levels, including full basement insulation, airtight construction, and high performance windows. A well built, well-insulated house will have a very small heat load, meaning the furnace doesn't have to contribute much, and you can use a very small heating system.

For domestic hot water, tankless gas fired units are very efficient. The conventional gas-fired tanks are very inefficient.

It is also important to ensure that the heating system is correctly sized for the heat load of the house. Over sizing will mean lower overall efficiency.

This is where a certified energy evaluator can help to review the energy performance of the house, and help to fine-tune the design specifications to minimize purchased energy consumption.

Gas fireplaces should be direct vent, sealed combustion units with electronic ignition. Every standing pilot light represents a significant cost both in terms of operating costs as well as contributing to overheating when heat is not required. These units can also supply a significant amount of heat when needed. In some areas, gas fireplaces are designed to be part of the heating system.

There is no fuel preference in programs such as Built-Green™, Energy Star, R-2000 or LEED. But there is an energy performance requirement that the house meet a minimum energy performance. This recognizes the importance of proper building design, reducing heat load and will require the use of high efficiency heating systems, and water heaters. Generally, the more efficient the mechanical system is, the higher the energy rating will be for the house as the efficiency of heating equipment and hot water heaters is considered. In addition, the mix of fuels in each region will vary.

However, in places with heavy reliance on thermal generation of electricity, such as Alberta and Saskatchewan, which rely on coal burning plants for most of their electricity, electrical heating definitely does not make sense.

Energy Answers

Rob Dumont

If you could have only one instrument to help tune up a house's energy use, what would it be?

A thermocouple temperature sensor would be my choice.

Most of the energy consumption in houses is used to maintain a temperature difference. For instance, house temperature in winter is usually held around 22°C, the hot water around 55°C, the refrigerator at about 4°C, the freezer at -18°C, etc. If these values are not right, you may be wasting a considerable amount of energy.

For measuring temperature, my favourite device is a thermocouple-based digital readout. The thermocouple has the advantage that it is quite rugged, can measure temperatures over a wide range, is not very sensitive to liquid water, and is relatively inexpensive. Thermocouples operate on the Seebeck effect. A junction of two dissimilar metals will generate a voltage if the junction is at a different temperature than the readout device. The readout device converts this voltage signal into a temperature. A schematic of the thermocouple and readout is shown in Figure 1. The voltage output from most thermocouples is quite small—about 40 microvolts per degree C – thus a sensitive readout is needed.

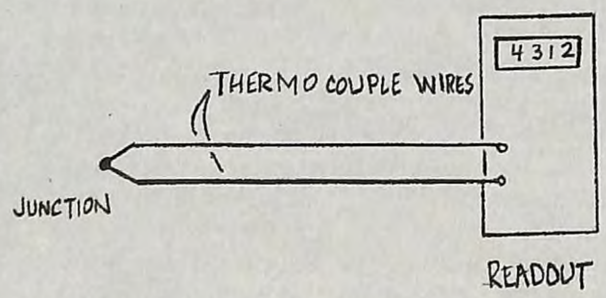

Figure 1. Thermcouple wires and a temperature readout

For about $150 you can get a dual input thermocouple readout with decent accuracy. Omega.ca has an Omegaette HH300 model that uses type K thermocouples, and I have been satisfied with their performance over the years. Some other suppliers include Fluke, Extech, and Cole-Parmer.

Here are some temperatures that can be checked using a thermocouple:

Refrigerator temperature. The desirable temperature should be about 4°C. A higher temperature will increase food spoilage, and a lower temperature will increase energy use.

Freezer temperature. The desirable temperature should be about -18°C. As with a refrigerator, a higher temperature will increase food spoilage, and a lower temperature will increase energy use.

Room thermostat. Use the thermocouple readout to check that your thermostat is reading properly.

Water heater temperature. The water temperature should be about 55°C coming out of the unit. Higher temperatures will waste energy and can cause scalding, and lower temperatures increase the risk of legionella and other bacteria growing in the unit.

Oven temperatures. The thermocouple can be used to cross-check the temperature settings on the oven dial and prevent uncooked or burnt food.

Furnace exhaust temperatures. A high efficiency condensing natural gas furnace will have an exhaust gas temperature of about 50°C or lower. A low efficiency conventional natural draft gas furnace should have an exhaust gas temperature of about 175°C as the exhaust gas leaves the heat exchanger. (We have, however, measured some exhaust gas temperatures as high as 400°C in cases where the warm air flow through the furnace was seriously impeded by bad ductwork or a dirty air filter.) A high exhaust gas temperature is a ready indicator of low efficiency.

Air-to-Air Heat Exchanger (Heat Recovery Ventilator). Use the thermocouples to check out the temperatures at the inlets and outlets of the HRV. For example, if the outdoor air temperature is -10°C and the indoor air temperature is +22°C, the temperature of the outside air should be about +13.4°C after it has passed through the HRV (this assumes that the sensible heat recovery effectiveness is about 70%). In addition, the temperature drop on the exhaust air side of the heat exchanger should be roughly equal to the temperature rise on the outside air side of the heat exchanger. For the above example

the temperature rise of the outside air would be 11.4 -(-10) = 23.4°C. The temperature fall on the exhaust air side of the heat exchanger should also be about 23.4°C if the air flows on each side of the heat exchanger are equal. (This assumes that condensation effects can be neglected.) Thus the exhaust air temperature after it has been cooled should be about 22 -23.4 = -1.4°C.

If the temperature rise and temperature fall values are quite different, the most likely reason is that the flows on each side of the exchanger are unequal. Adjust the flows to bring the HRV into balance.

Skin temperature. Your skin temperature is usually about 30°C. If it is less than or equal to room temperature, you are likely dead, and you need read no further.

Thermocouples can be fooled if not used properly. Here are some common errors with using thermocouples:

1. The junction of the thermocouple must be in thermal equilbrium with the temperature of the object being measured. Make sure that the thermocouple wire is in contact for at least an inch (25 mm) with the surface being measured. For instance, if you place only the tip of a thermocouple on your skin, the temperature will read about 25°C which is clearly too low. If, however, you tape the thermocouple tip and an inch of wire near the tip to your skin, you will get a temperature of about 30°C which is much more accurate.

2. Ensure that the insulation on the two wires is intact. If the wires are shorted at a place other than the tip, the thermocouple will give an inaccurate reading.

3. Periodically check the calibration of the thermocouple. An accurate check can be made by placing the thermocouple junction and about an inch of the wire into an ice bath. The ice bath should consist of a mixture of water and crushed ice. The thermocouple should read very close to 0°C.

4. Watch out for radiation sources, as they can give a false reading of temperature. For instance, a thermocouple that is exposed to direct sun outdoors will give an inaccurate reading of the air temperature. A radiation shield such as a toilet paper cardboard wrapped with aluminum foil will work well. A thermocouple inside an oven will give an inaccurate reading of temperature if the thermocouple is placed near the hot element.

Temperature is probably the most important parameter in a dwelling. It pays to have a good temperature sensor. ☼

NRC·CNRC

Gypsum Board Performance in Fire Rated Floor Assemblies

By M.A. Sultan

Gypsum board is a versatile material that finds widespread use in frame construction. In addition to its role of providing a finished surface for walls and ceilings, when installed and fastened according to code and standards-prescribed specifications, gypsum board plays the crucial role of imparting frame construction with fire resistance abilities.

The National Research Council's Institute for Research in Construction (NRC-IRC) completed a comprehensive research initiative that tested many building assemblies, most with fire rated Type X gypsum board, to establish the fire resistance ratings and related sound transmission class (STC) ratings. The results of the research generated much of the information in Part 9 Appendix A, Table A-9.10.3.1.B. of the 2005 National Building Code (NBC) of Canada. The research confirmed the importance of gypsum board for the fire resistance of framed assemblies and revealed some interesting information about the performance of gypsum board in fire situations.

Some Facts about Gypsum Board

Gypsum board is manufactured in panels consisting of a non-combustible core bounded by paper surfaces. Several types of core and facing combinations are available that impart special characteristics such as enhanced fire performance (Type X) or enhanced performance in high-humidity applications, to give two examples.

For fire performance, the gypsum core is usually composed of at least 75% pure gypsum and up to 25% additives such as glass fibre and vermiculite as well as other materials to reduce the likelihood of cracking and shrinkage when panels are exposed to heat. The gypsum core is chemically combined with about 21% of water by weight. In addition, gypsum usually contains a small amount of absorbed free water. As the gypsum is heated to a temperature in excess of 80°C, it begins to undergo a thermal degradation that eventually affects the ability of panels to remain in place to deter the spread of smoke, flame and heat to adjoining rooms.

In fire situations, the ability of the gypsum board to remain in place depends on the characteristics of the board, the quality of the fastening and other factors. This highlights the importance of ensuring that, for constructing a given fire-resistance rating, installers use the specified fastener length and spacing and joints are sealed (tape and joint compound) to resist the spread of flame between panels as long as possible.

Research

The NRC-IRC research assessed the gypsum board fall-off time for 80 full-scale fire resistance floor test assemblies using lightweight framed wood joists, wood-I joists and steel joists, and wood trusses, protected with either one or two layers of Type X gypsum board. The gypsum board used had the Firecode C Core Type X designation and met the requirements of Type X gypsum board.

The research investigated several variables that could potentially affect fall-off time including:

- Effect of resilient channel installation and spacing
- Effect of insulation in the cavity between joists
- Effect of one versus two layers of gypsum board
- Effect of framing type (solid wood joists, wood I-joists and steel C joists) and spacing

A floor assembly was considered to have failed when one of the following failure criteria as per the CAN/ULC S101-04 Standard occurred first:

- A single point temperature reading measured by one of nine thermocouples under insulation on the unexposed surface rose 180°C above the ambient temperature;
- The average temperature measured by nine thermocouples installed under insulated pads on the unexposed surface rose 140°C above the ambient temperature;
- There was passage of flame or gases hot enough to ignite cotton waste;
- The assembly was no longer able to bear the applied load.

Findings

The research produced the following findings:

- Gypsum board fall-off time had a significant effect on the fire resistance of lightweight frame assemblies - the longer the gypsum board stayed in place the better the fire resistance.
- A second layer of gypsum board increased the fall-off time for the gypsum board layer exposed to the fire (face layer) compared to an assembly with only one layer of gypsum board, even though the base layer fell off relatively quickly compared to the face layer due to a thermal shock caused by board exposure to heat once the face layer had dropped off.
- The type of framing had no significant effect on gypsum board fall-off time.
- The installation of resilient channels did not affect significantly the fall-off time for gypsum board compared to an assembly without resilient channels. However, changing the spacing of the resilient channels from 406 to 610 mm had a negative effect on the fall-off time, while changing the spacing from 406 to 203 mm had no significant effect.
- Fall-off time was affected by the distance the fasteners are situated from the panel edges. Increasing the screw distance from the edge of the panels from 10 to 38 mm increased the fall-off time considerably. This can be achieved by using Type G screws to attach the face layer to the base layer in a two-layer gypsum board floor system, or by using Type S screws to attach a board in a single-layer floor system to two side-by-side resilient channels as illustrated at the end of the NBC Part 9, Appendix A, Table A-9.10.3.1.B.
- The presence of insulation in the floor cavity had a negative effect on the fall-off time of gypsum board for assemblies with both one and two layers of gypsum board.

This research significantly advanced the understanding of how gypsum board affects the fire resistance of floor assemblies and how frame assemblies behave in fire situations. One perplexing finding was the detrimental effect that insulation in floor cavities has on gypsum board fall-off time; this will be the topic of further research.

For further information about completed and planned research regarding the influence of gypsum board on the performance of framed assemblies, contact Dr. Mohamed Sultan at tel. 613-993-9771 or e-mail: Mohamed.sultan@nrc-cnrc.gc.ca. The full research report is available at http://irc.nrc-cnrc.gc.ca/pubs/fulltext/nrcc45420/.

Dr. Mohamed Sultan is a Senior Researcher and Leader of the Fire Resistance and Risk Management Group at NRC-IRC.

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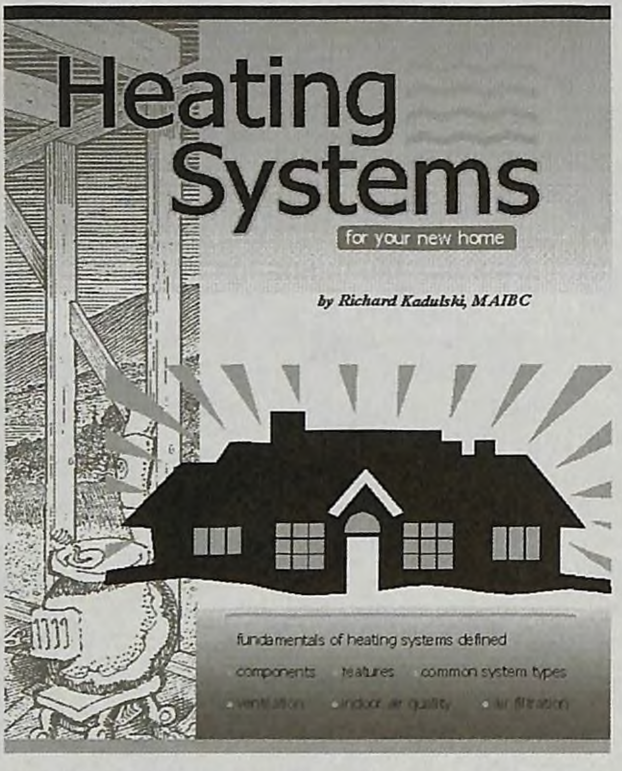

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